Metabolic Processes – Cellular Respiration & Photosynthesis

**STEP ONE:**

**DON’T PANIC**

Metabolism: “The sum of all chemical reactions in a cell of organism”

Important idea: Concept of energy transfer. Specifically, chemical energy and light energy.

**3.1 – Energy & Shiznit**

*First law of thermodynamics:* Energy is not created nor destroyed, only transformed.

Potential energy: Energy stored within an object and is dependent on the objects location or chemical structure. Chem. Potential energy is stored in the electrons and protons that make up atoms and molecules. (Prevalent in chemical bonds!)

* During a rxn the amount of potential energy changes
* During a rxn energy is always absorbed and released
* The further away electrons are from the nucleus, the more potential energy
* Electrons reach “excited” state when they move further away from the nucleus
* Energy transferred in chemical rxn’s via absorption and release of energy in order to break bonds and when they are made

Bond energy: Measure of strength of a covalent bond (kj/mol). Amount of energy is absorbed when bonds are broken. Bond energy = amount of energy release when the same bonds form. \*This is influenced by situation the specified bond is in.

Activation energy: The amount of energy needed for a rxn to start (bonds to break). Act. energy = diff. between pot.energy of reactants and pot.energy during transition state.

Transition state: Reactant’s bonds are broken, no new bonds have yet formed

Exothermic RXN: More energy is released during rxn than absorbed. (Products have LESS pot. Energy than reactants)

Endothermic RXN: More energy is absorbed than released during rxn. (Products have MORE pot. Energy than reactants)

*Second law of thermodynamics*: In every energy transfer, some energy is wasted.

Cellular resp. allows us to use like 40% of total energy we get, so we waste 60% as thermal. (Makes me feel better about how I use about 0.4% energy into studying and the rest into internet use.)

Entropy: A measurement of disorder in a system.

Spontaneous Change: A change that once started will continue on its own. (Can be spontaneous in different ways. That change is a strong independent one who don’t need no man)

Ex. of spontaneous change: Burning (Energy released is enough to keep rxn going)

Ex. Of non spontaneous change: Photosynthesis (requires constant supply of energy)

Free Energy: Energy that can do useful work \*Also “Gibb’s Free Energy” (wonder why…) It’s the energy that’s not wasted, basically. Change in free energy (∆G):

∆G = GFinalstate – Ginitialstate

\*Negative ∆G value indicates spontaneous rxn.

Exergonic RXN: Rxn that releases free energy. Products have LESS free energy than reactants

Endergonic RXN: Rxn that absorbs free energy. Products have MORE free energy than reactants.

Energy Coupling: Basically referring to spontaneous reactions. Cells make endergonic rxn’s (those that need a constant energy supply) by utilizing the energy of exergonic reactions. (think about it) This is more efficient because they just have to start the exergonic rxn’s which will go on their own and fuel the endergonic rxn’s.

*SCIENCE BREAK:* WOWOWOW THINK ABOUT IT ALL THIS FRICK FRACK IS GOING ON INSIDE OF YOU RIGHT NOW. WITHOUT EVEN THINKING ABOUT IT. HOW COOL IS THAT. LEMME TELL YOU, SUPER COOL. COOLER THAN AND ENDOTHERMIC REACTION. HAHAHAHA okay back to work.

Metabolic Pathway: Series of rxns where the products of one rxn are the reactants of another. This goes along in a big happy rxn chain.

* Catabolic Pathway: Rxns where (overall) energy is released, complex molecules are broken down into simpler ones (ex. Cellular resp.) Overall ∆G = -’ve\*
* Anabolic Pathway: Rxns where (overall) energy is used to build complex molecules (ex. Photosynthesis, protein/nucleic acid synthesis.) Overall ∆G = +‘ve\*

\* Pathways are made up of many reactions, not all reactions may have same ∆G value as the overall pathway

\* Regardless of overall ∆G, each endergonic step will need an exergonic step to proceed.

This free energy for reactions is generally supplied as ATP (adenosine triphosphate). Say What???

**3.2 – ATP Runs the Show**

ATP does mechanical, transport and chemical work.

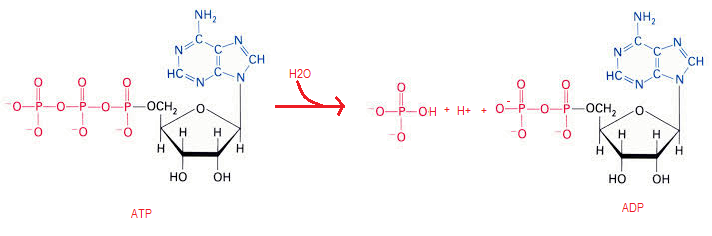
Consists of three parts:

A nitrogenous base called adenine, which is linked to a 5 carbon sugar, “ribose”. This ribose is linked to 3 phosphate groups. ATP has a lot of free energy available because the phosphate groups are negatively charged. They are close together and so they repel each other while still being bonded to one another. (so cray) This makes their bond weak. They are very easily broken via hydrolysis.

If one Phosphate group breaks off, then there will be one Pi (inorganic phosphate) and ADP. Also, H+ ions will be released into the solution. Free energy is released when these form.

\*\* (Think about it) It’s easy to break the PO4 groups apart, so it requires little energy. However, much more energy is released. This results in a net release of energy. Bing bam boom you got some free energy.

ATP + H2O 🡪 ADP + Pi (∆G = -30.5kl/mol) “dat free energy!”



ATP can be used for energy coupling because it’s super at giving away free energy.

Phosphorylation: The end phosphate group transfers to the reactant molecule. This makes the reacting molecule have more free energy and makes it become more reactive. (Wow thanks phosphate u r a pal.) You need an enzyme to do this. After the rxn you’re left with the product and a Pi.

*SCIENCE BREAK: THIS IS ONLY ONE EXAMPLE WITH TWO STEPS BUT SOME OF THIS SHIZNIT HAS MILLIONS OF STEPS LIKE HOW RAD IS THAT?? YOU KNOW HOW MUCH ENERGY I NEED TO TAKE A MILLION STEPS? OH WAIT ATP DOES THAT FOR ME TOO I GUESS DAMN SCIENCE IS SWEET.*

But the trouble aint over yet – we need to keep making ATP so we need to synthesize it again once it’s used! However, synthesizing ATP requires energy. To regenerate ATP we use the free energy from macromolecules (carbs, fats, proteins, which we eat) to put the ATP back together again. *THIS HAPPENS 10 MILLION TIMES EVERY SECOND.* HOLY CRAP.

**3.4 – Food as Fuel**

Glucose & Gasoline are good fuel sources because of their C-H bonds. The electrons involved here are attracted to the small nuclei of carbon and Hydrogen. “In Addition to distance from the nucleus, the size of the nucleus influences the pot. energy of an electron.”

This makes them easy to move to bigger nuclei and release more energy. This is an example the contrasts molecules with a lot of Oxygen bonds, because O is super duper electronegative and does not want to let go of any of those electrons. It can hold on to two electrons super tightly and they lose pot. Energy when they are bonded to O (because it’s going to take a shiznit amount of energy to remove them again.)

\*\* Explains why fat has more energy per unit of weight compared to sugar / protein because fats are made up of a lot of C-H bonds.

Redox Reactions:

* Oxidation: Electrons in a bond spend are considered to be “owned” by another. One party loses electrons to another. OIL. This one is called the reducing agent.
* Reduction: An atom or molecule gains electrons. RIG. This one is called the oxidizing agent.

\*\* Sometimes the electrons transfer completely from one to another, and sometimes they stay sort of shared. (Yes chemistry is fricken complicated)

This movement of electrons releases energy which can be used for other things. It’s kinda like the reaction helps itself along.

Energy Carriers

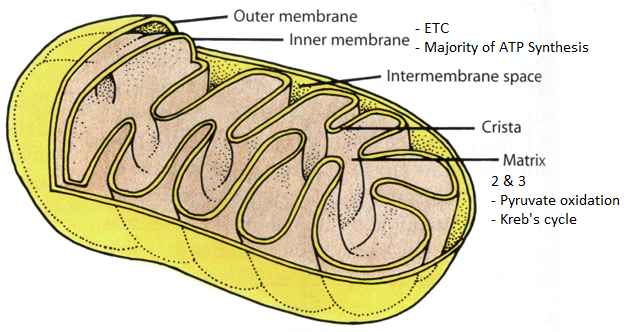
The most important redox reaction in cells is when glucose is oxidized to form carbon dioxide and water. Enzymes called “Dehydrogenases” oxidize a substrate and transfer H+ ions to an acceptor.

**4.1 – Cell. Resp & Fermentation**

Aerobic cell. Respiration: A process that uses oxygen to harvest energy from organic compounds.

* Gets energy from food to synthesize ATP from ADP + Pi
* C6H12O6 + 6O2 🡪 6CO2 + 6H2O (∆G = -2870kj/mol 🡪 use to synthesize ATP) (wow) We are obligate aerobes for this reason.

*There are FOUR stages to cell. Resp.*

1. Glycolysis (CYTOSOL)
2. Pyruvate Oxidation or “oxidative decarboxylation” (MITOCHONDRIA)
3. Citric Acid or Kreb’s Cycle (MITOCHONDRIA)
4. Electron Transport Chain (ETC) & Oxidative Phosphorylation (MITOCHONDRIA)

*You can get ATP out of it by one of TWO ways:*

1. Substrate level phosphorylation: “The formation of ATP by the direct transfer of a phosphate group from a substrate to ADP”
2. Oxidative Phosphorylation

Image:

<http://taksreview.wikispaces.com/>

file/view/Mitochondria.jpg

*BUT WHAT IF THERE’S NO OXYGEN?!?* Fear not – there are two solutions…

Anaerobic Respiration: “A process that uses a final inorganic oxidizing agent other than Oxygen to produce energy” (Cell.Resp. Without O2)

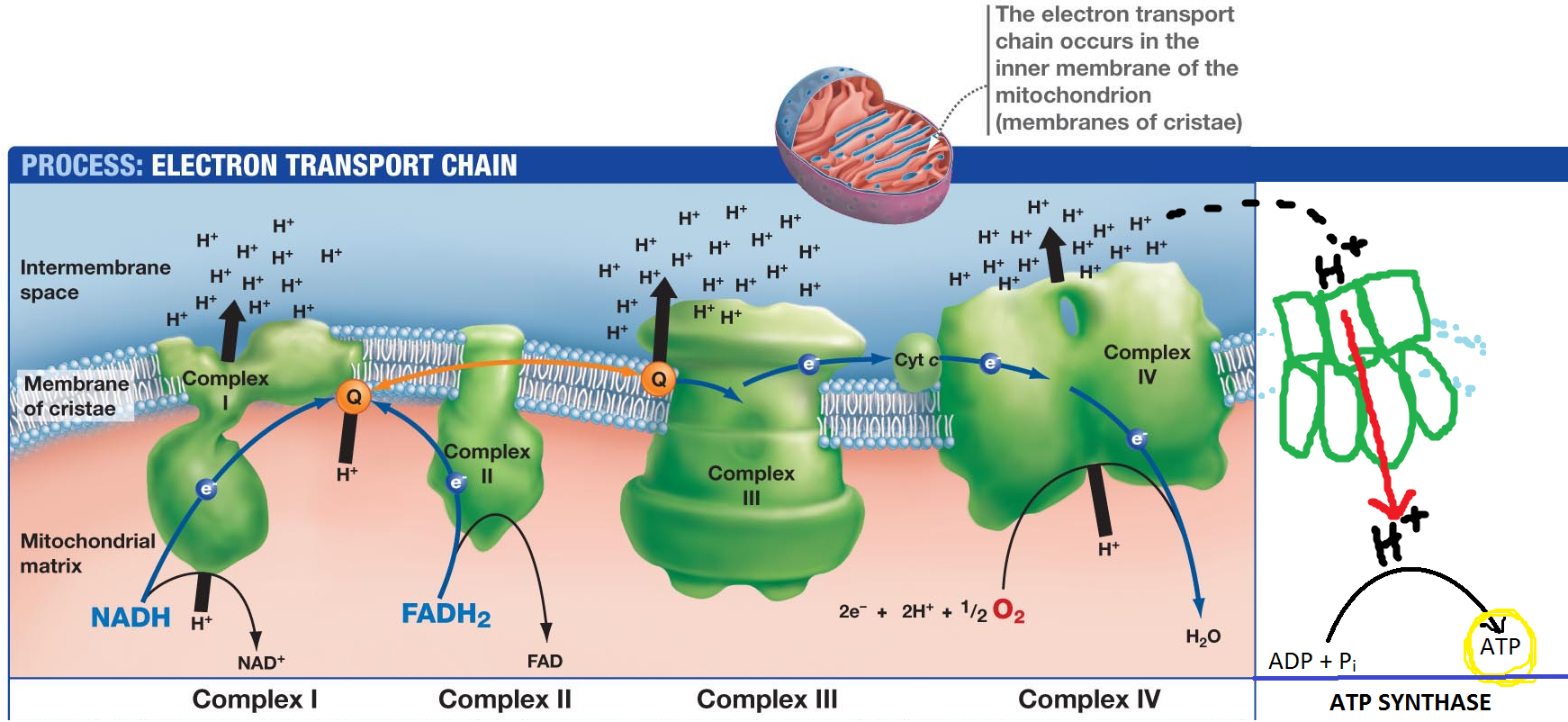
Fermentation: “A process that uses an organic compound as the final oxidizing agent to produce energy”

These both work and will both yield some free energy to synthesize ATP, however it’s a shiznit amount LESS than aerobic cell. Resp. That sucks, but hey, you gotta do what you gotta do.

Some creatures (like us) are obligate aerobes. We need O2. Some creatures (like Trichonympha) are obligate anaerobes. They can’t have any O2. Then there are some creatures (like E.Coli) are facultative anaerobes. They can deal with either one.

**4.2 – Shiznit gets real INDEPTH**

Let us delve into the wonder that is cellular respiration. *Ooh ahh*.

(SEE NEXT PAGE FOR FLOW CHART DIAGRAM)

The Electron Transport Chain

* Each complex (made of proteins with electronegative R groups) is more electronegative than the previous, pulling the electrons from NADH & FADH along the chain. NADH has the most free energy, but Oxygen is the most elect.neg.
* The most electronegative thing, however, is the Oxygen atom waiting near Complex IV. It combines with 2H+ ions and the two e- from the complexes it pulled and makes H2O.

Image: http://www.uic.edu/classes/bios/bios100/lectures/09\_21\_electron\_transport-L.jpg

*In the meantime:*

Whilst the electrons from NADH & FADH are moving, they release energy that is used to pump H+ ions across the membrane. A shiznit amount accumulate in the intermembrane space.

\*\*This is a *proton gradient*- and it’s a form of potential energy! *BUT WHY?!?*

A chemical gradient exists because the concentration of protons on each side of the membrane is not equal. The protons are also charged, so they repel each other and are attracted to the inner membrane. These factors combined is called *the proton-motive force.*

Chemiosmosis: “The ability of cells to use the proton-motive force to do work.” Aka. The fact that ATP can be synthesized from ADP + Pi using the energy from the proton gradient. The proton gradient basically makes protons “activate” the ATP synthase making it like a cute little motor which catalyzes the formation of ADP + Pi to ATP.

Efficiency:

1NADH = 3 ATP 1FADH2 = 2 ATP

Glycolysis (2ATP) + Kreb’s Cycle (2ATP) + ETC (34ATP) = Max of 38ATP per glucose

Too bad we aren’t 100% energy efficient so this isn’t reality. Glucose has 2870kj/mol of energy while we really get 1178kj/mol out of it. (Awkward.) But in the grand scheme of things this is a pretty good amount of use of energy, surprisingly.

Metabolic Rate: The amount of energy that is expended per unit time in an organism

Basal Metabolic Rate (BMR): The metabolic rate of an organism at rest.

*SCIENCE BREAK: BUT THIS SHIT IS ALMOST LIKE IT CAN THINK ON ITS OWN BECAUSE IT REGULATES ITSELF. THAT’S RIGHT, SCIENCE IS GOING ALL STAR TREK ON YOUR BUTTS. GET READY FOR SOME CONTROL.*

**4.3 – Efficiency and Regulation of Cell. Resp.**

(See next page diagram)

*BUT WHAT’S WITH ALL THIS GLUCOSE?!? I DON’T LIKE SUGAR!!! WILL I DIE??*

First of all, you’re crazy, but second of all, not necessarily. Fat and Protein can be used for this whole cycle too but shiznit gets a little cray because they have to enter at weird times because they are different. Glucose is used first, then other carbohydrates, then fat, then protein.

(See next next page diagram)

Beta Oxidation: A process in which fatty acids are broken down into acetyl-CoA through catabolism.

Question: Why do I store a bunch of fat but I’m not jiggly by a bunch of glucose?

Your body stores fat that way because it’s Hydrophobic and you don’t need to also store that much water as you would with glucose. *Oooh ahhh.*

**4.4 – Anaerobic Pathways: Life without Oxygen**

Two methods of getting energy out of food when you’re living in an oxygen-less world: Fermentation and Anaerobic Respiration. DIAGRAMS: p.191 - 192

Fermentation

If there is no oxygen, how can electrons or protons be moved around without its high electronegativity? Life has found a solution. Anaerobic respiration involves fermentation. There are many different types of fermentation but there are two main types we’ll focus on:

1. *Alcohol Fermentation*

(Or Ethanol fermentation). 2ATP will be put together when glucose turns into pyruvate via glycolysis. The pyruvate made through glycolysis will be decarboxylated into acetaldehyde. This acetaldehyde can oxidize NADH into NAD+. (By acting as an acceptor and becoming ethanol) This NAD+ is needed to keep replenishing steps for glycolysis, and helps to continue the cycle.

Pyruvate + NADH + H+🡪 NAD++ CO2 + ethanol (🡪 = acetaldehyde inside )

Because you get two pyruvates for each glucose, you’ll get two ATP’s, a release of CO2 and ethanol as a waste. Overall equation:

Glucose + 2 ADP + 2Pi 🡪 2ATP + 2CO2 + 2 ethanol

\*\* Real world application: CO2 release in yeast is used in bread to make it rise

1. *Lactate Fermentation*

This is used in a lot of bacteria and whatevs, but humans still use this as a backup! We use this when we’re working out and getting super swoll (pshh, yeah right – I’m on tumblr) because we can’t get enough oxygen to our ETC fast enough! So BOOM – no oxygen required. What goes down: We start glycolysis and turn glucose into pyruvate. In this time, 2ATP are put together. However we still need a constant supply of NAD+ to keep the cycle going – the used NAD+ (now NADH) wont work! SO now good guy pyruvate will turn NADH into NAD+ and become lactate, allowing the NAD+ to go back to help glycolysis.

Pyruvate + NADH + H+🡪 NAD++ lactate

Glucose + 2 ADP + 2Pi 🡪 2ATP + 2 lactate

*SCIENCE BREAK:*  *TALK ABOUT WHEN LIFE GIVES YOU LEMONS. YOU AINT GOT OXYGEN? NO WORRIES PAL FERMENTATION FIGURED OUT A WAY TO MAKE LIFE GO ON ANYWAYS. GOOD GUY FERMENTATION KEEPS ITS REAL. NAD+? MORE LIKE SUPER RAD+!*

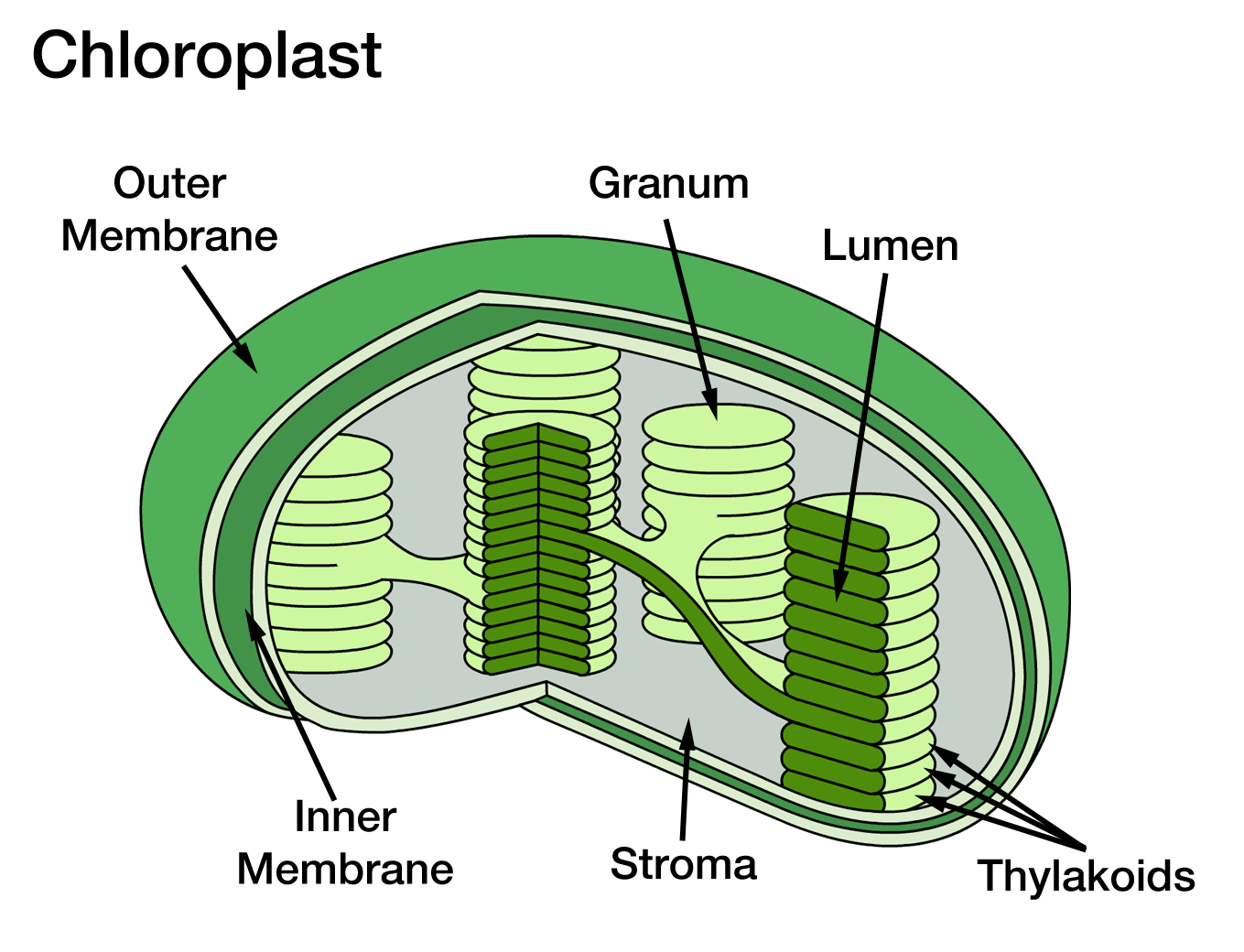
**5.1 - Photosynthesis**

And you thought animals were cool turning food into energy like magic. Well guess what – plants may see all calm and whatever but in reality they are super cool because they can turn SUNLIGHT into fricken glucose. So what should we call these things that have such a superpower? God? Dumbledore? Nope – *photoautotrophs.*

Two stages of photosynthesis: (Both occur inside the chloroplast)

1. Light dependant reactions (Water + sunlight = oxygen via ETC)
2. Light independent reactions (Carbon Dioxide to glucose via Calvin Cycle)

\*\* Both work in unison to make the general photosynthesis equation work:

6H2O + 6CO2 🡪 C6H12O6 + 6O2  (🡪 = sunlight)

Both the light dependant and light independent cycles occur inside the chloroplast that has three membranes: the outer membrane on the outside, the inner membrane just inside that, and then the aqueous environment inside called the stroma.

Inside the stroma there is another membrane system: the thykaloid membrane. They make a series of disks that are called grana (single: granum). The space inside a thykaloid membrane is called the thykaloid lumen.

Image: http://www.artinaid.com/wp-content/uploads/2013/04/Structure-of-Chloroplasts.gif

Thykaloid membrane = light dependant reactions

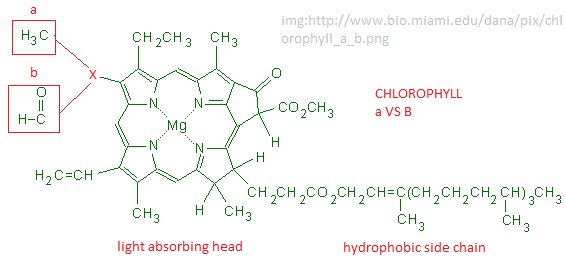
*That’s great, but how does this shiznit get energy from the sun?*

A photon is absorbed by a pigment molecule (chlorophyll). This gives enough energy for an electron in the “ground” state (energy shell close to nucleus) to become “excited” and move further away. Once this happens there are three possible outcomes for out little electron friend:

1. The electron just releases its excited energy via heat or fluorescence and returns to ground state
2. The electron releases enough energy to excite a neighbouring electron on a pigment molecule, then returns to ground state.
3. The excited electron is accepted by an electron accepting molecule called the “primary acceptor”

\*\* Step c) is what we really want to happen the most, it’s important.

This most commonly used pigment that has the electrons is called chlorophyll. There are two versions of this that have slightly different structures. We call them chlorophyll a and chlorophyll b. (In bacteria instead of chlorophyll you have bacteriochlorophylls.) The second major group of pigments is called the carotenoids.



Chlorophyll b & carotenoids are called accessory pigments because once they get energy they just transfer it to chlorophyll a. They, together, are called *the antenna complex* because of this. They transfer the energy to chlorophyll a which then transfers it to the primary electron acceptor in the *reaction center.*

But let’s not carried away – this aint magic – plants can’t absorb ALL the wavelengths of the light, they are picky. The ones they don’t absorb pass through the leaf or are reflected. (The reflected ones are the colours we see.) Each kind of pigment absorbs different spectrums of wavelengths. We can put this info on two graphs (right, like I needed more graphs after functions)

1. *Absorption Spectra* is a plot of the amount of light energy of various wavelengths that a substance absorbs.
2. *Action spectrum* which is used to plot the effectiveness of light energy of different wavelengths in driving a chemical process. The data is collected by testing to see how much O2 comes out of a plant when it’s exposed to different wavelengths of light. (SCIENTIST ENGELMENN DID ONE OF THE FIRST OF THESE)

So after all of this energy is transferred to the chlorophyll a’s, where does it go? Well good guy chlorophyll a donates (it gets oxidized) an electron to a primary electron acceptor, and then it’s donated again to the electron carriers. All of this is called a photosystem, and exists within the plant’s own ETC. Two important photosystems:

Photosystem I: (P700) absorbs light at the 700 nm wavelength

Photosystem II: (P680) Absorbs light at the 680nm wavelength.

\*\* P = pigment

**5.2 - Pathways of Photosynthesis**

**LIGHT DEPENDANT REACTIONS:**

**Linear** Electron Transport and ATP Synthesis:

Light energy is absorbed by the accessory pigments, then transferred to P680. P680 loses an electron to the Prim.Elec.Acceptor, which then makes it negative and P680 positive. This makes P680 SUPER DUPER electronegative (like, as in the strongest fricken biological oxidizer) and pretty much makes it go super saiyan - powerful enough to SPLIT WATER via the water splitting complex. WOWOWOW. It takes 2 electrons from water and releases 2H+ and 1/2O2.

These electrons are then transferred via plastiquinone (PQ) to plasticyanin, which transfers them to P700. PQ also moves protons from outside of the thykaloid membrane to inside (the lumen). More light is absorbed, p700 is oxidized and moves electrons to the second electron acceptor. The electrons then go to ferredoxin. Then they move to the NAD+ reductase.

Then the electrons are put to work: 2H+ + NADP+ 🡪 H+ + NADPH

MEANWHILE: The proton gradient formed inside the lumen powers the ATP synthase, turning: ADP + Pi 🡪 ATP

\*\* The NADPH and ATP formed then move on to the calvin cycle (light independent reactions)

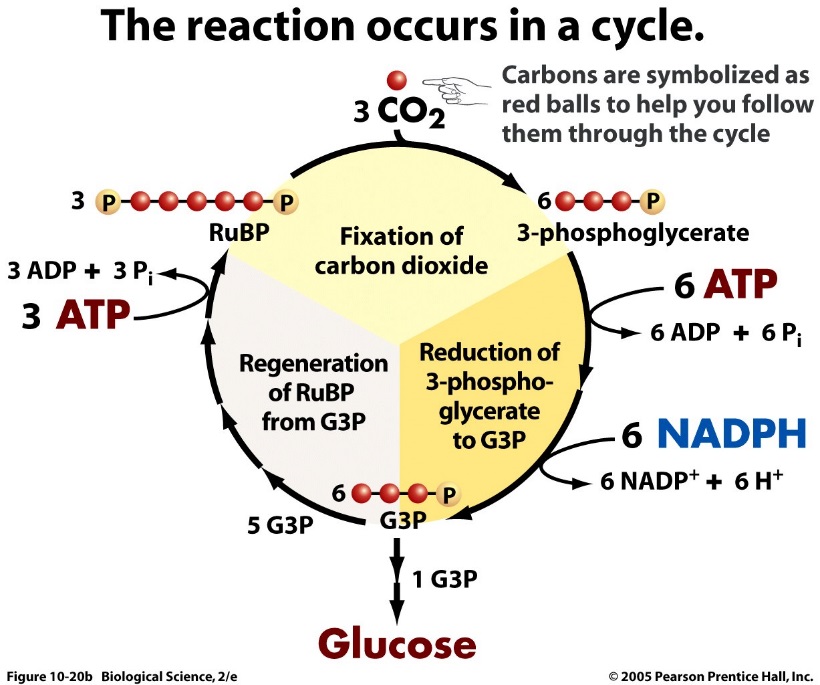
\*\* To move one electron, you need two photos of light: one @ photosystem 1, and another at photosystem 2.

**Cyclic** Electron Transport and ATP Synthesis:

Photosystem I (with P700) can function independently of photosystem II. Basically what is going on here is that photons of light enter photosystem I (P700) to remove electrons from P700, which then move to the electron acceptor, to ferredoxin, to PQ, to plastocyanin and then back to P700. Meanwhile, protons join the cycle by moving along with PQ and are dropped off inside the thykaloid lumen. This powers the movement of protons and the proton gradient to power ATP synthase and make ATP from ADP + Pi.

This occurs when YES! I need ATP! But NO I don’t need NADPH! (The Calvin cycle needs more ATP than NADPH so this can help sometimes)

**LIGHT INDEPENDANT REACTIONS:**



The calvin cycle is the final thing that will transform our products and finally make glucose, which is what we promised in the general photosynthesis equation. There are three steps to this: fixation, reduction and regeneration.

Img: <http://www.uic.edu/>

classes/bios/bios100/

f05pm/calvin.jpg

1. Fixation: Turning carbon from an inorganic to an organic form. CO2 reacts with “ribulose-1,5-biphosphate” (“RuBP”) to make 3-phosphoglycerate. (This is called C3 metabolism!) (VIA RUBISCO ENZYME)\*\*\*
2. Reduction: Each molecule of 3-phosphoglycerate gets a phosphate when ATP goes under hydrolysis. THEN this thing is reduced by high energy electrons from NADPH to form glyceraldehyde-3-phosphate (“G3P”). (2G3P = 1glucose)
3. Regeneration: Some of the G3P molecules then go back and are combined and rearranged into RuBP to fuel the cycle again.

\*\* In one complete cycle, you’ll get one reduced carbon: CH2O. It takes THREE cycles to make one of something the cell can use. The above picture is “a summary of three cycles”. (see p.227 for carbon tracking summary)

This cycle needs: 9 ATP, 6 NADPH (for three cycles)

\*\*\* Rubisco: “ribulose-1,5-biphosphate carboxylase oxygenase” catalyzes the CO2 x RuBP reaction (SUPER DUPER IMPORTANT)

*SCIENCE BREAK: DEAD DUDE “MELVIN CALVIN” (WHAT A FRICKEN NAME) FIGURED THIS SHIZNIT OUT BY PUTTING RADIOACTIVE CARBON 14 INTO REALLY SPECIFIC PARTS OF THIS UNKNOWN CYCLE SO HE COULD TRACK THE MOVEMENT OF CARBON ATOM BY ATOM. THAT’S SOME DETAILED SHIZNIT, SON.*

**5.4 – Alternative Mechanisms of Carbon Fixation**

Stomata: Holes in the leaf that allow gas exchange. Lose water during day, they close at night to conserve water.

Photorespiration: Rubisco sometimes screws this whole shiznit up because it can also work as a catalyst for RuBP and oxygen instead of carbon dioxide, which wastes times and energy to fix. Rubisco likes to bind to carbon dioxide MORE, but oxygen if oxygen is there, it may bind to it. (Rubisco is also super slow, binding 3CO2 per second. But there’s a lot of it so it’s okay.)

This becomes a big problem in hot, dry climates because of how the solubility of the gases work around the stomata. The CO2 to O2 ratio becomes smaller, and there’s even more O2 present for rubisco to bind to. Photorespiration increases. LUCKILY, PLANTS HAVE EVOLVED TO SURVIVE YET AGAIN! WOWOWOW.

**C3 Plants:** The regular plants that use all the shiznit above.

**C4 plants:** These plants have adapted to live in hot, dry climates. They have altered their structure and added a step to combat photorespiration. To get to the calvin cycle & rubisco, CO2 enters into the mesophyll cell and has to go through the C4 Cycle to get to the calvin cycle. CO2 combines with a 3-carbon molecule called phosphoenolpyruvate (PEP) to make 4-carbon oxaloacetate (via CO2 loving enzyme PEP carboxylase.) That is then reduced to malate by electrons transferred from NADPH. The malate then diffuses into an even deeper set of cells call the bundle-sheath cell. It enters a chloroplast and is oxidized to pyruvate, releasing CO2 which goes directly into the calvin cycle from there. The pyruvate become PEP again by

\*\* Although C4 plants need a lot more ATP for this to work (needed to turn pyruvate back into PEP) it cuts down stupid photorespiration and requires less rubisco, too. It’s Bueno all around.

**CAM (Crassulacean acid metabolism) Plants:**

C4 plants have their C4 cycles and calvin cycles running in different cells, but at the same time. Some plants however can run these two cycles in the same cells but at different times of the day. (Wowowow) These are called CAM plants.

These plants live in places where it’s hot and dry in the day but cold at night. (like cacti) The stomata open at night and let O­2 out and CO2 in. The CO2 is converted into malate. This malate is stored in the vacuoles overnight in the form of malic acid. Then as the sun rises, the stomata close to prevent water loss and gas exchange. The malate is oxidized to pyruvate, and a shiznit amount of CO2 is released. The calvin cycle then proceeds.

**5.6 – Photosynthesis and cellular respiration: A comparison**

These processes are complementary. They are meant for each other. Life is so cool.

**5.? - PHOTOSYNTHESIS AND THE ENVIRONMENT**

EFFICIENCY: (See on next page cont’d w/ graphs) Otherwise…

*SCIENCE BREAK: HOLY CRAP YOU DID IT GOOD JOB!! YES THIS GOLD STAR IS FOR YOU, YOU ARE A SUPERSTAR NOW GO OWN THAT TEST! (OR KEEP READING FOR MORE)*

Molecular Genetics – The Secrets of Life

**STEP ONE:**

**DON’T PANIC**

Let’s begin with the **important dead guys** who did all the work to discover that this shiznit exists. There are a lot but these dudes/ladies are hella smart so give em some credit.

1. *MIESCHER (AKA. MR. GROSS)*

* Took PUSS from his patient’s bandages and found a ~mysterious substance~ inside the nucleus
* This material was found not to act like proteins (at this time, proteins were thought to be the hereditary material because there were a lot of them)
* This shiz was acidic and had a lot of phosphorus – Mr. Gross named it “nuclein”

*Conclusion: Nucleus is the location of hereditary info.*

1. *HAMMERLING (MR. THOR ALGAE)*

Experiment 1:

1. Cut cap off of “acetabularia”…the cap regenerated!
2. Foot (containing nucleus) was removed. The foot was not regenerated.

*Conclusion: Nucleus controls the physical characteristics of an organism.*

Experiment 2:

1. Used two types of algae this time: orenulata and meditterrania – both had different coloured caps. He Transplanted/grafted foot from one to the other. The caps grew to be a mix of both of the two.
2. Took transplanted mixed plants and cut off the caps. The original caps grew back!

*Conclusion: Nucleus confirmed to be location of hereditary material.*

1. *AVERY AND GRIFFITH (BACTERIAL MICE KILLERS)*

* Nucleus was accepted as the location of hereditary material
* Focused on the role of DNA in diplococcus pneumonie bacteria (2 forms):

WITH CAPSULES: (cause deadly pneumonia) = S-STRAIN (S for sucks to suck)

WITHOUT CAPSULES: (non pathogenic) = R-STRAIN (R for rockin the life idk)

Experiment 1:

1. Healthy mice injected with R-Strain = LIVED

Experiment 2:

1. Healthy mice injectd with s-strain = DIED

Experiment 3:

1. Heat treated s-strain and denatured the protein coating capsule of bacteria
2. Mice injected with heated s-strain = LIVED

Experiment 4:

1. Mice injected with a mix of heated s-strain and regular r-strain injected = DIED

This is evidence of ~transformation~. DNA of one goes into another and the foreign DNA is expressed. The R-strain bacteria were transformed with DNA of s-strain

*Conclusion:*

1. *HERSHEY AND CHASE (MR. CHOCOLATE & BACTERIA)*

* Bacteriophage is a virus that attacks a host (bacteria)
* Showed that only DNA from bacteriophage enters the bacteria (not the protein coat) to direct the synthesis of new viruses
* At the time was unclear if DNA was protein or nucleic acid

Experiment:

1. Radioactive 35S was added to the bacteriophage virus: This labelled the protein because proteins have S & no P
2. Radioactive 32P was added to bacteriophage virus: This labelled the DNA because they have a shiznit amount of P

*Conclusion: DNA is a nucleic acid because only the radioactive P was transferred into the bacteria to continue virulent activity. Bing bang boom DISCOVERED.*

1. *EDWIN CHARGAFF (MR.RATIO)*

* This dude was sassy af and didn’t believe there were equal amounts of the 4 nitrogenous bases in DNA like everyone else
* He looked at purine(Adenine (A) and Guanine (G)) vs. pyramidine (Thymine (T) and cytosine (C)) composition in DNA samples
* Measured ratios of base pairs A:T & C:G (they were similar in many species)
* This totally meant that this pairing was for a reason. Lead to the notion of complementary strands??
* Not same ratios of each (25%/25/25/25), but instead: (human)

A-30.9%, T-29.4%, C-19.9%, G-19.8%

(pairs have same ratios as their partner awe how sweet)

*Conclusion: Complementary base pairs have equal ratios of each other, not all base pairs have the same ratio.*

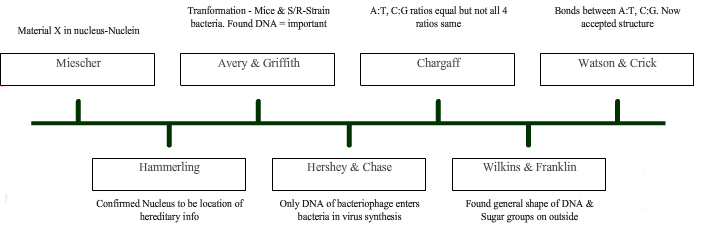
1. *WILKINS AND FRANKLIN (SHAPE FINDERS)*

* Used x-ray crystallography to find basic “X” shape of DNA
* DNA diameter = 2nm
* One turn of double-helix clockwise = 3.4nm

*Conclusion*: Shape & The phosphate groups formed backbone of DNA, not on the inside

1. *WATSON AND CRICK (INFO CONNECTORS)*

* Drawing on their own research and other’s they got together the now accepted structure of DNA
* Double helix DNA with purine & pyramidine pairings (A=T, G---C) from one helix to another
* Pairing held together by hydrogen bonds (two for A=T and three for G---C) therefore G/C harder to separate
* Helices arranged anti-parallel to one another (one spiralling up right, one spiralling down right)



kjkj

*SCIENCE BREAK: YO DUDE THOSE SCIENTISTS ARE HELLA SMART AND HELLA RAD THEY FRICKEN DISCOVERED DNA SHIZ WHILE HERE I AM JUST DRINKING TEA AND WATCHING TOO MANY TV SHOWS*

**6.4 – DNA REPLICATION & REPAIR**

Meselson and Stahl (more scientists) did some super cool research and found DNA to replicated *semi-conservatively.*

Semi-Conservative replication: Each strand of a “parent” DNA double helix goes into the making of a separate complementary strand. (ex. If your parent DNA had two purple strands, and the new material was marked as red, the new DNA strands would be half red then half purple…etc etc see p.282)

\*\* DNA replication occurs during interphase (Section S) of cell division

(SEE NEXT PAGE FOR DIAGRAM)

*SCIENCE BREAK: BABY YOU CAN CALL ME HELICASE CUZ I’D LIKE TO UNZIP YOUR GENES. ;)*

The packing of Eukaryotic DNA:

DNA double helix folds around 8 histone proteins to form a *nucleosome*. These (6) nucleosomes group together to form *solenoids*, which wind up to form a *chromosome*.

Telomere: Act like aglets at the end of chromosomes. Are repeating non-coding sequences of nucleotides. Uses:

* Prevent chromosomes from binding to each other
* Prevent nucleases from degrading DNA
* Help the DNA repair things do their work by distinguishing chromosome ends
* Play a role in determining how many times a given cell can divide

Cell senescence: “Cell Aging” cell loses ability to divide and grow

Hayflick Limit: The number of times a cell can divide.

Telomerase: Enzyme that adds new telomerase sequences to ends of chromosomes.

Small sections of the end of each DNA strand is lost during replication. To prevent loss of critical info, telomeres act as the cushion so they get removed instead of useful stuff. Eventually they wear down themselves and that causes ‘cell aging’ because there if there is no more telomere, DNA info will be lost and the cell’s division is compromised.

\*\* The ratios of A-T and C-G are the same inside of DNA, but they are not all 1:1:1:1.

**The Process of Replication:**

1. *Gyrase* unwinds DNA. *Helicase* unzips DNA.
2. *Single-Stranded Bonding proteins (SSB’s)* attach to each individual strand to keep them from re-bonding.
3. *Primase* puts down *RNA Primers* that will indicate where to replicate. This reads 3’-5’ and so builds primers that align in the complementary 5’-3’ direction.
4. *DNA Polymerase III* reads the strands 3’-5’, and builds DNA nucleotides from 5’-3’, following the primers. It is easy to do this on the 3’-5’ strand, or *leading strand*, but one half of the original template DNA will be facing 5’-3’. Therefore, the primers and polymerase must build from the replication fork UPWARDS, building in pieces as the template DNA continues to open. These pieces are called *Okazaki Fragments*.
5. Once finished, *DNA Polymerase I* “excises” (cuts out) the RNA Primers.
6. *DNA Ligase* joins the Okazaki fragments together by creating phosphodiester bonds.
7. *DNA Polymerase I & II* proofread the strands to fix any mistakes.

*SCIENCE BREAK: YEP THIS SHIZNIT CHECKS ITSELF BEFORE IT WRECKS ITSELF!!*

**Function of Genes:**

One Gene Hypothesis: “Each gene is unique and codes for the synthesis of a single enzyme”

Beadle & Tatum

* Did an experiment with neurospora (bread mold) X-rayed the shizet out of them and made them Mutants.
* These mutants could no longer break down / use the nutrients the original ones could.
* This lead to the thinking that the DNA had been compromised meaning no more proteins made to break down that shit.

**Protein Synthesis:**

* DNA does not just replicate – it encodes to be decoded
* DNA is *synthesized* during replication, but it is *transcribed*  (Into useful proteins) during protein synthesis

DNA is like an encyclopaedia at the library. You can’t take it out, so you photocopy pages and study off those. DNA replicates into RNA strands, and these ones that do protein synthesis are called mRNA. This mRNA is then translated into polypeptides in the cytoplasm, which eventually become active proteins.

Three classes of RNA:

1. mRNA: the info that is transcribed into the final protein
2. tRNA: transfers the appropriate amino acid to the ribosome as determined by the mRNA
3. rRNA: structural component of the ribosome site of protein synthesis.

*Now that we know that shiznit, Protein synthesis is made up of two major processes:*

1. **TRANSCRIPTION:**

* DNA is transcribed into RNA via the replication process. Two complementary strands of RNA are made. (One for each strand of template DNA, leading and lagging)
* RNA changed into mRNA contains the coding for a specific protein

Post transcriptional changes:

1. Addition of 5’ cap (consisting of seven “G’s”) which protects the RNA from digestion by enzymes
2. Removal of “introns” (non-coding regions, or the shiznit of the RNA we don’t need) using spliceosomes. We keep the “exons” (or the shiznit we DO need.)
3. Addition of a poly-Adenine tail (Like 20-30 “A’s”). This extends the life of the RNA.

*But this shiznit needs to be changed MORE before we can get bro-tein!*